An Economic Analysis of Alternative Fertility Control and Associated Management Techniques for the Pryor Mountain Wild Horse Herd

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Executive Summary

Contemporary cost projections were computed for several alternative strategies that could be used by BLM to manage the well-studied Pryor Mountain wild horse population. The alternatives included (1) existing contraceptive, gather and selective removal methods; (2) different contraceptive techniques offering effectiveness of greater duration; (3) manipulation of herd sex ratio; and (4) a gather and removal-only scenario. Costs were projected for a 20-year economic life using the Jenkins wild horse population model and cost estimates from BLM that reflect this herd's specific removal, adoption, and contraceptive application expenses. Important findings include:

- The Pryor Mountain herd has a low intrinsic growth rate that tends to moderate wide inter-annual population fluctuations and greatly minimizes cost differences among contraceptive scenarios.
- All contraceptive scenarios have roughly equal costs compared with exclusive gather and removal management without contraceptive application.
- Treatment with contraceptives under the existing application protocol is predicted to be approximately 50% less costly than gather and removal management alone.
- Annual application via darting is cost-effective on this herd compared with more "conventional" contraceptive applications every 4 years even if the contraceptives have a long (3-year) duration. However, the longer-acting contraceptives reduce the expected inter-annual variability in average expenses.
- The Alternative Baseline scenario is predicted to be the least expensive option, but the consistent treatment of all older aged mares called for in this scenario is unlikely to be sustainable over a 20-year period without reducing the population below desired AML levels.
- Average annual costs would decline slightly if the herd's sex ratio were adjusted to leave more males on the range, but care must be used not to remove too many mares of prime foaling age lest the population decline below desired levels.
- In general, cost estimates are most sensitive to annual monitoring expenses, not to direct contraceptive or removal/adoption costs.
- The 4-year gather cycle is appropriate for this herd, though costs are not very sensitive to the gather frequency.

Introduction and Objective

This report is an addendum to a previous economic analysis conducted by USGS for BLM that examined contraceptive and management options for three wild horse populations (Bartholow 2004). The sole focus of this current report is the Pryor Mountain wild horse herd, which has previously been subject to contraceptive treatment. Management flexibility is, however, important, and treatment regimes may change through time. The current report examines some potential management alternatives in a manner that is generally parallel to, but not identical with, Bartholow (2004).

The BLM's goal for the Pryor Mountain herd is management at a clearly established appropriate management level (AML) at minimum cost. Alternative means to achieve this goal are explored in this report and include: (1) the status quo of annual contraceptive application, selective removal and adoption; (2) the frequency of gathers and how efficient they are in rounding up animals; (3) status quo plus several alternative contraceptive application scenarios, specifically the duration of the contraceptive agent and using contraceptives annually or in concert with a 4-year gather cycle; and (4) other potential management techniques, such as sex ratio manipulation through age- and sex-specific removal decisions.

Study Area

The Pryor Mountain Wild Horse Range was established in 1968 and occupies 38,000 acres of multi-jurisdictional lands along the border of Montana and Wyoming, about 13 miles north of Lovell, Wyoming. This mostly arid Range supports about 100-200 wild horses in a largely free-roaming condition. Harsh winters and abundant predators may help limit the number of older animals (with few >16 years old) and contribute to variable, and intermittently high, foal mortality. Conflicting management perspectives stimulated research on several issues germane to proper management of this population, including vegetation dynamics and population genetics (Singer and Schoenecker 2000).

Fertility control research began on the Pryor Mountain herd in 2001 and continued in 2002 and 2003. Contraceptives have been applied using remote darting techniques not necessarily associated with regular gathers. Darting uses an initial primer and annual booster, and can take place over a period of time, reaching 100% of the mares targeted for the contraceptive program. BLM currently envisions giving the contraceptive agent porcine zona pellucida (PZP) vaccinations to all yearling and 2-year-old mares and those 14 years and older, allowing younger mares to mature in a healthy state prior to the rigors of pregnancy and allowing older mares to live their senior years in better overall health. This protocol, termed “compassionate-use” fertility control, is envisioned to improve mare health, reduce foal loss, and help prevent orphaned foals.

Additional information concerning this herd is available from BLM (USBLM 2004).

Methods

Step 1. Define Baseline and Specific Alternatives

This analysis examines the following scenarios:

- Baseline Scenario – Existing "baseline" conditions as reflected in current management policy (USBLM 2004). This is a regular 3-4 year gather with age-specific removal rates, specifically 50% for age classes 1, 2 and 3, and 25% of 4-year olds. It is assumed that 100% of horses removed are targeted for the adoption pool, and are held an average of 30 days prior to adoption. Removals are assumed never to end up in long-term holding facilities.

  "Compassionate-use" fertility control involves 100% treatment for yearling and 2-year old mares, and also for mares 14 years and older. Under the baseline scenario, contraceptives are applied via annual darting and do not require gathering.

  Unfortunately, existing management of the Pryor Mountain herd can only be approximated by the current Jenkins model. The limitation arises because the model does not allow for dual management (contraceptives and removals) on two different frequencies (annual and 4-year) at two different efficiencies (100% for contraceptive darting and only 70% for gathers). Further, the cost estimation program does not allow differing costs for contraceptive application that might occur in conjunction with a 4-year gather as opposed to annual darting. In order to approximate existing management, I ran the Jenkins model on a 1-year gather cycle, but removed animals at one-fourth the removal rate that would have occurred if it had been a 4-year gather Actually, I used a rate of 0.175 [0.7 x 0.25] to account for the normal gather efficiency of 70% (Table 1). This technique is not a completely faithful representation for all the reasons mentioned, but it should reasonably approximate baseline costs.

  Table 1. Comparison of removal rates for annual darting scenarios and conventional 4-year gather cycle. Rates for annual darting scenario are 0.175 times the rates for the regular gather scenarios, but must be rounded to the nearest whole percentage for the Jenkins model.

Age class	Regular 4-year gather scenarios	Annual darting scenarios
0	0	0
1-3	50	9
4	25	4

  One other model adaptation concerned handling removal rates for 14-year old horses. The Jenkins model lumps older animals into ages 10-14, 15-19, and 20+. I approximated removal of older animals by spreading applicable rates among the age classes, with values derived from Linda Coates-Markle.

  Efficacy rates for dart-delivered contraceptives are shown in Table 2, along with rates for more conventional contraceptives, discussed below.

- Alternative Baseline – Modification of the Baseline Scenario being considered for the Pryor Mountain herd. This alternative is identical to the Baseline scenario except that it also treats 50% of all <u>other</u> age classes (3-13) with contraceptives.

- Conventional Contraceptive Scenarios – These scenarios are meant to represent contraceptive strategies being used, or anticipated, on many other BLM-managed wild horse herds (USBLM 2002), and are similar to those investigated by Bartholow (2004). Instead of the annual darting, contraceptives would be applied solely in conjunction with a regular 4-year gather cycle, and nominally represent either 2- or 3-year duration, defined more precisely with percent effectiveness in the first and subsequent years as shown in Table 2.

  Contraceptives are assumed to be applied to all mares returned to the range. Note that it is considered to be the case, and the Jenkins model assumes, that if the vaccine does not produce infertility in the first year for a given mare, it would never be effective in subsequent years until re-treatment. The 1-year scenario values also given in Table 2 represent values found with annual darting on the Pryor Mountain herd and used in conjunction with the Baseline scenarios, while the 2-year scenario values represents values from a recent assessment of a different herd.

  Table 2. Annual effectiveness of existing and potential contraceptive treatments. These are gross efficacy rates that are further tempered by age-specific fertility rates in the Jenkins model. Values for 1- and 2-year treatments confirmed by Linda Coates-Markle. Values for 3-year agent were liberally extrapolated from 2-year efficacy rates. One-year contraceptives represent the effectiveness achieved through darting (primer and booster).

Nominal Duration	Effectiveness Year 1 (%)	Effectiveness Year 2 (%)	Effectiveness Year 3 (%)	Effectiveness Year 4 (%)	Effectiveness Year 5 (%)
1-year	90	0	0	0	0
2-year	94	82	68	0	0
3-year	94	82	68	33[1]	0

  [1] Since running these simulations, newly collected data are available for the Clan Alpine herd (J.W. Turner, Jr., technical notes on Clan Alpine HMA Wild Horse Survey, June 2004, supplied by Linda Coates-Markle). These notes do not support 4th year effectiveness. Therefore, the cost estimates for scenarios involving the 3-year contraceptive will, of necessity, be too low.

- Gather Frequency Scenarios – represent regular gather interval in years (e.g., 2, 4, 6, or 8 years).

- Sex Ratio Scenarios – represent long-term changes to the herd sex structure by favoring removal of horses of one sex over another during the normal selective removal process (e.g., 60% male to 40% female). Note that sex ratios will usually not match among the alternatives. This is because the sex ratio is generated by long-term changes to sex- and age-class specific removal rates and could not be precisely predicted by specifying population model inputs. In other words, a sex ratio resulting from a given simulation might or might not have been what I was trying to achieve.

- As appropriate, combinations of the above scenarios have been considered. For example, 3-year Contraceptive/Sex ratio-55 would mean the combination of a 3-year contraceptive duration and 55 male:45 female sex ratio. All unspecified parameters are the same as the baseline case, unless otherwise stated.

- Removal-only – One removal-only (no contraceptive application) scenario was included solely for cost comparison.

Step 2. Organize Jenkins Model Input Data and Parameters

Data representative of the Pryor Mountain Herd Management Area (HMA) were compiled and organized in a fashion suitable for the Jenkins wild horse population model (Jenkins 2002). Much of the vital background and operational philosophy for the Jenkins model has already been supplied by Bartholow (2004) and will not be repeated here. Pryor Mountain HMA data and modeling parameters were taken from a Jenkins' model data set and other information supplied by Linda Coates-Markle in early 2004, greatly simplifying this effort. I assumed that the data accurately described the Pryor Mountain population's demographics. A summary of important demographic parameters for this herd is given in Table 3 and a complete listing of the baseline data set for the Pryor Mountain herd is given in Appendix A.

Table 3. Key demographic elements and information concerning compassionate-use fertility control for the Pryor Mountain HMA considered in this analysis.

	Pryor Mountain
Initial population sex ratio (% male)	53
Sex ratio at birth (% male)	51
Age 0-9 female survival (geometric mean %)	89
Age 0-9 male survival (geometric mean %)	87
Average foaling rate age 2-9 (%)	62
Gather trigger (# of horses)	150
Gather efficiency (%)	70
AML (# of horses)	100
AML includes foals?	No
Released mares treated for contraceptive alternatives by age	Foals: 0% 1 & 2 year: 100% 3-13 year: 0% 14+: 100%

Step 3. Exercise the Jenkins Model for Each Scenario

Each scenario was run as a separate simulation using model input parameters to describe the various management actions that might be taken, contraceptive effectiveness, and so on. I have assumed that the Jenkins model provides a reasonably accurate portrayal of population dynamics and that model results can then be used in evaluating a variety of cost-minimization strategies.

Values or settings for the Jenkins' WinEquus model used in Pryor Mountain simulations were:

- Simulations were run for 20 years (producing 21 years of simulation output) with 100 trials each (100 trials is the default)
- Gathering for removal occurred at regular 4-year intervals
- When fertility control was used:
  - Gathers for fertility control occurred regardless of population size
  - Gathers continued after removals to treat additional females to be released (default if the above condition is true). Note, however, that the percentage of females actually treated by age class depends on other model input.
- Scaling factors for annual variation, which interestingly come from Garrott and Taylor (1990) and therefore specifically represent the Pryor Mountain herd:
  - survival probabilities = 1.00 (default)
  - foaling rates = 1.00 (default)
- Correlation between annual variation in survival probabilities and foaling rates = 0.00 (default). According to Linda Coates-Markle (May 2004), there may be some evidence supporting a non-zero correlation for the Pryor Mountain herd due to density-dependent phenomena. However, since these scenarios are explicitly meant to stabilize the population within rather narrow density limits, I left the correlation at zero.
- Initial population size is exact and unsmoothed [different from previous simulations (Bartholow 2004)]
- Foal survival is not density dependent (default)
- Minimum age of sanctuary-bound horses: Not applicable (default)

Step 4. Estimate Dollar Value for Each Management Cost Component

Dollar values were estimated for the main gathering, treating, and selective removal expenditures, along with associated costs related to wild horse management. Dollar figures were taken from Bartholow (2004) and supplemented with information provided by Linda Coates-Markle (Table 4). These costs represent FY 2004 values, but are assumed to increase 3% annually regardless of geographic area to parallel the inflation rate BLM uses for planning. Removal costs include all expenses of gathering and transport to adoption facilities, averaged across all removed horses. Preparation and holding costs include freeze branding and required vaccinations. Adoption costs are largely administrative and include follow-up compliance checks (site visits to adopted horses).

Table 4. Variable cost estimates for the Pryor Mountain wild horse population. Cost estimates were supplied by Linda Coates-Markle, BLM/MT (5/24/2004) and differ from those listed for Montana in Bartholow (2004) because they include labor as a variable cost.

Removal Cost (/horse)	Prep & Holding Cost (/horse/day)	Adoption Cost (/horse)	Compliance Check (/horse)
$800	$40	$1100	$225

Costs used in this analysis for multi-year contraceptives are given in Table 5. Several other potential costs were also considered in the analysis. It was assumed that the minimum gather cost was $15,000, whereas a value of $10,000 was used previously by Bartholow (2004). This comes into play only if the number of animals removed times the appropriate per horse removal cost would be below $15,000. However, for the Baseline and Alternative Baseline scenarios, I used a minimum cost of $3,750 ($15,000/4) to allow gathering and contraceptive application every year in the model, as discussed previously. Though this modification may underestimate costs when real 4-year gathers round up few horses, it represents the best approximation available.

A $5,000 per year HMA census cost was applied for non-gather years to assess contraceptive treatment effectiveness and routine monitoring per the recommendation of Ron Hall (2003). Though the Pryor Mountain herd does not employ census flights due to intensive on-the-ground monitoring, labor costs for this monitoring are roughly equivalent to Hall's cost recommendation and are treated identically in this analysis. However, census costs are problematic for the Baseline and Alternative Baseline scenarios because gathers occur every year in the simulation, though not in reality, and the cost estimation program only tallies a census expense if no horses are gathered. To make up for these "missing" census costs, I added back the $5,000 expense for the 15 years the census would have occurred, averaged over the 20-year period. In other words, I added $3,750 to the average annual cost estimated for the Baseline and Alternative Baseline scenarios to properly account for underestimating census costs (5000*15/20).

Table 5. Estimated per horse costs for contraceptive application. Costs for the 1-year agent represent $20 for the primer and $20 for the booster, plus an additional $66 for labor ($11 per hour times 6 hours per mare, on average) to find and apply the darts. Costs for the 3-year agent are composed of the total cost of a 2-year agent plus additional 12-month time-release pellets. Estimates derived from Linda Coates-Markle (BLM/MT) 9/30/2003 and 5/26/2004.

Contraceptive Duration	**Estimated Cost per Horse**	**Comment**
1 year	$106	Remotely applied by darting
2 years	$214	Applied with gather
3 years	$309	Applied with gather

Step 5. Estimate Dollar Costs from Simulated Scenarios

The results of the Jenkins model simulations were summarized and converted to dollar expenses over a 20-year planning horizon. Tallying the total expenditures required all cost estimates previously described, including which ages were eligible for adoption and how long adoptable horses are held. Note that the Pryor Mountain population never contributes unadoptable animals because only young age classes are removed. Results were summarized by software that computed the mean number of horses gathered, removed, and treated by sex and age class for each year of the 20-year simulations, along with average annual costs. In addition, the cost summarization step computed the likely annual variation in costs that would be expected as a result of the variability inherent in the Jenkins model.

Step 6. Conduct Sensitivity Analysis

The Jenkins simulation model captures environmental and demographic variability, but the uncertainty in cost estimates for the various management options remained to be explored. To accomplish this, a sensitivity analysis was performed for the Pryor Mountain population to see where opportunities for cost cutting might lie and which factors contribute most to the bottom line.

Results

Results for the Pryor Mountain HMA are given in Table 6 and Figures 1-4. The results confirm that a four-year gather cycle is a good management decision, though there is not much difference among the alternatives (Figure 1), presumably because the herd is so closely controlled no matter which scenario is chosen – an artifact of this population's low growth rate. Interestingly, a 6-year gather cycle is predicted to be more costly than an 8-year cycle. Annual costs are insensitive to gather efficiency (Figure 2), but are somewhat responsive to slight changes in sex ratio (Figure 3). Even eliminating male removal all together, simulations suggest that the sex ratio would not rise much beyond 53-54% males. In an attempt to further elevate the sex ratio, I increased the female removal rates by 50% (i.e., from 50% on age class 1 to 75%), but this had virtually no affect on the long-term sex ratio and increased the average annual management costs. Results from these experiments are not shown in Table 6.

Average annual cost estimates (Figure 4) are relatively uniform across many of the alternatives, with the exception of the removals-only case. The Alternative Baseline scenario is predicted to be the least expensive, but also has a significant negative effect on the herd's growth rate over the long term. Inspection of the results across the alternatives suggests that growth rates below minus 1.0% are likely too aggressive and cannot be sustained over the 20-year period without significantly increasing the probability of falling below the 100-horse AML. This is also true with scenarios designed to leave more males on the range. Care must be taken to not remove too many mares of prime foaling age lest the population decline below desired population levels.

There is a noteworthy difference reflected in the coefficient of variation between the darting scenarios and the more conventional 2- or 3-year contraceptive scenarios (Table 6). This is presumably due to the lack of longevity of the 1-year contraceptive used in darting versus the persistent effects of the 2- and 3-year contraceptives.

It is important for the reader to understand that running the same parameters through the Jenkins model repeatedly can produce very different sets of results due to the random nature of the simulations. This randomness can produce variations on the order of 5% or more. Because Table 6 records the mean annual cost from just one set of 100 trials for each scenario, one must use caution when interpreting the results. In short, predicted mean costs for many of the contraceptive scenarios given in Table 6 may or may not be significantly different from one another in a statistical sense. Statistical differences were not assessed in this analysis because one could always increase the number of trials, thus assuring significant differences without any true justification.

Table 6. Summary of results for scenarios of the Pryor Mountain HMA.

Scenario	Average Annual Cost ($)	Percent of Baseline Cost (%)	Median Annual Growth Rate (%)	CV (%)
Baseline	11019[1]	100	-0.7	154.3
Alternative Baseline	7717[1]	70	-4.3	146.7
2-year contraceptive	12877	117	+0.2	82.7
3-year contraceptive	12283	111	0.0	86.3
2-year contraceptive/ Sex ratio-53	10941	99	-0.8	71.0
2-year contraceptive/ Sex ratio-54 (No male removal)	9585	87	-1.3	64.1
3-year contraceptive/ Sex ratio-52	10700	97	-0.2	67.2
3-year contraceptive/ Sex ratio-53 (No male removal)	10157	92	-1.2	62.3
3-year contraceptive/ 2-year gather cycle	12376	112	-1.4	126.0
3-year contraceptive/ 6-year gather cycle	14022	127	-0.1	82.7
3-year contraceptive/ 8-year gather cycle	13206	120	+1.2	59.8
3-year contraceptive / -10% gather efficiency	12294	112	+0.2	77.5
3-year contraceptive / +10% gather efficiency	12141	110	-0.7	91.9
Removals only	16049	146	+0.9	80.0

[1] Includes $3,750 to make up for "missing" non-gather year census costs, but is likely an underestimate due to inability to accurately reflect the $15,000 minimum gather costs when removals are low.

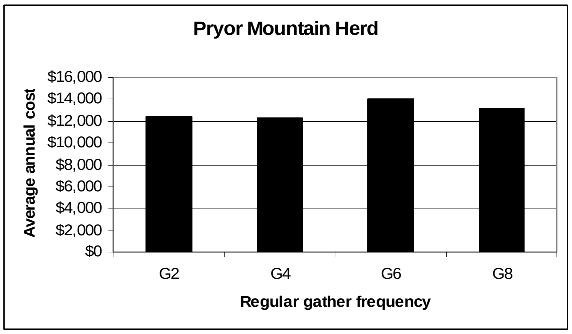

Figure 1. Annualized cost over a 20-year period for four gather frequencies for the Pryor Mountain HMA (G-2, 4, 6, and 8 years, respectively).

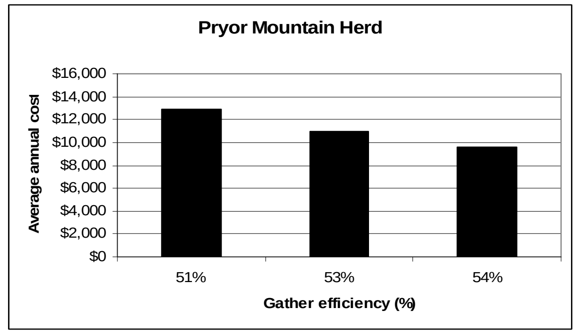

Figure 3. Annualized cost over a 20-year period for three resulting sex ratios associated with 2-year contraceptives for the Pryor Mountain HMA (51, 53, and 54% male, respectively).

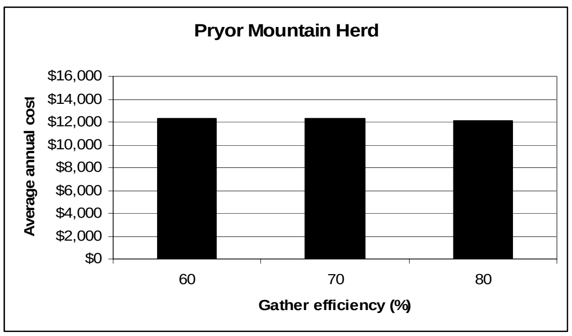

Figure 2. Annualized cost over a 20-year period for three gather efficiencies for the Pryor Mountain HMA (60, 70, and 80%, respectively).

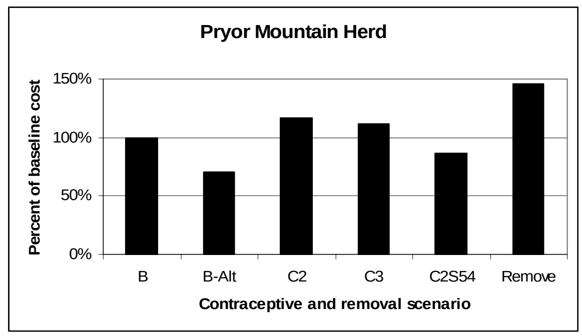

Figure 4. Percent of Baseline cost over a 20-year period for six scenarios.

Sensitivity Analysis for Cost Components and Related Factors

A basic sensitivity analysis was completed for the various elements that contribute to the cost estimate for the Pryor Mountain herd. This analysis tests how sensitive bottom line costs are to small changes in each contributing factor. Figure 5 was generated by changing each cost and management factor ±10% and taking the ratio of the resulting cost fluctuation to the base cost of the Baseline and Alternative Baseline Scenarios for the Pryor Mountain herd. I did not test the sensitivity of varying age thresholds because these are essentially fixed for this herd, though additional scenarios could explore some of these options.

The results indicate that annual monitoring is the cost component that would benefit the bottom line total expenses if it could be reduced regardless of the scenario. Then, for the Baseline Scenario, the next most sensitive cost factors are the costs of adoption, average per day holding costs (the somewhat mislabeled *$/Unadoptable/day* in this case), and number of days held until adoption. Costs related to contraceptive treatment and gathering fall in line next for the Baseline scenario, followed by the minimum gather cost, which contributes little to the sensitivity, indicating that that cost is trivial compared with other management expenses.

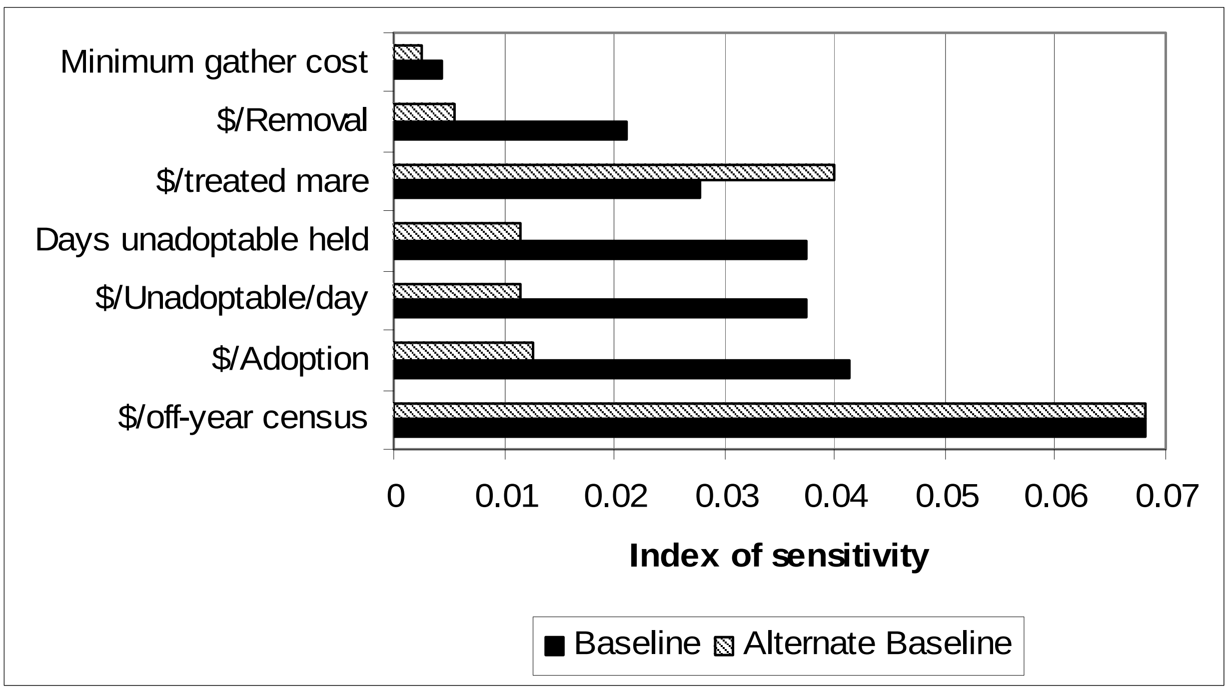

Figure 5. First order sensitivity analysis for management costs and other attributes for the Pryor Mountain herd.

Results for the Alternative Baseline scenario (Figure 5) were considerably different after the monitoring costs. Most factors were far less important for this scenario, relative to those monitoring costs, except for the contraceptive treatment costs. In other words, because this alternative treats far more age classes of adult mares, these additional costs add up significantly. This is not to say that these additional treatment expenses may not be cost-effective, because they are (Table 6). Rather, it simply says that if these treatment costs could be reduced, the savings would be substantial.

Conclusions and Discussion

The Pryor Mountain herd does not appear to have the same "vitality" as the three populations previously studied (Bartholow 2004). Based on the best, most recently collected data, male and female survival rates for the Pryor Mountain population are estimated to be less than 90% per year, in contrast to above 90% for the other three herds, and moderate foaling rates in the low 60% range are well below the average for the other three populations (72%). Collectively, these differences mean that the intrinsic growth for this herd is far lower than that for other populations, with median annual growth rates near 1% for the Removal-only scenario compared to about 17% for the three populations studied previously. BLM personnel confirm that the current Pryor Mountain growth rate is near zero and has not been above 10% for the last decade (Linda Coates-Markle personal communication). This implies that contraceptive treatment and removals for the Pryor Mountain herd can be far less intensive than for many herds yet still achieve cost savings. It also implies that small changes in management emphasis can result in undesirable negative growth rates.

The Pryor Mountain herd exhibits a higher expected annual variation than any of the herds examined previously. In part, this is a misleading conclusion because the high coefficient of variation can also result if there are no horses ever going into long-term holding facilities, thus creating large differences between gather and non-gather years. However, the Jenkins model simulations also suggest that the population fluctuates more widely *around* the 100-horse AML level rather than generally being *above* that level more often than not, as seen in simulations for other populations. For example, a few of the randomly-generated simulation traces resulted in fewer than 50 horses under the Baseline scenario (Figure 6). This phenomenon points to an additional weakness inherent in how the Jenkins model was applied here that was not discussed by Bartholow (2004): management actions such as contraceptive application would not continue unchanged for 20 years if the result of that application were perceived as jeopardizing the population's persistence. Adaptive assessment and management would prevail.

Caveats discussed in the initial report (Bartholow 2004) apply to this analysis. Several other concerns or imperfections with the Pryor Mountain modeling, particularly with trying to approximate the Baseline scenarios, have also been noted in this report. One additional caveat is worthy of mention. Recall that one goal of compassionate-use fertility control for the Pryor Mountain herd is to help reduce mortality of older mares and help prevent orphaned foals. Simulations conducted here did not include these potential feedback mechanisms and there is no way to conveniently do so. Research must continue to determine whether compassionate-use fertility control is successful in reducing these mortality sources.

Bartholow (2004) made some recommendations for potential modifications to the Jenkins model. Application of the WinEquus model to this specific herd was not a perfect fit for a variety of reasons. If there are other BLM-managed herds similar to the Pryor Mountain population that intermix annual darting and gathering, BLM might consider developing a model that could be tailored to these sorts of conditions. If this is the only herd, software modifications would not likely be worth the effort.

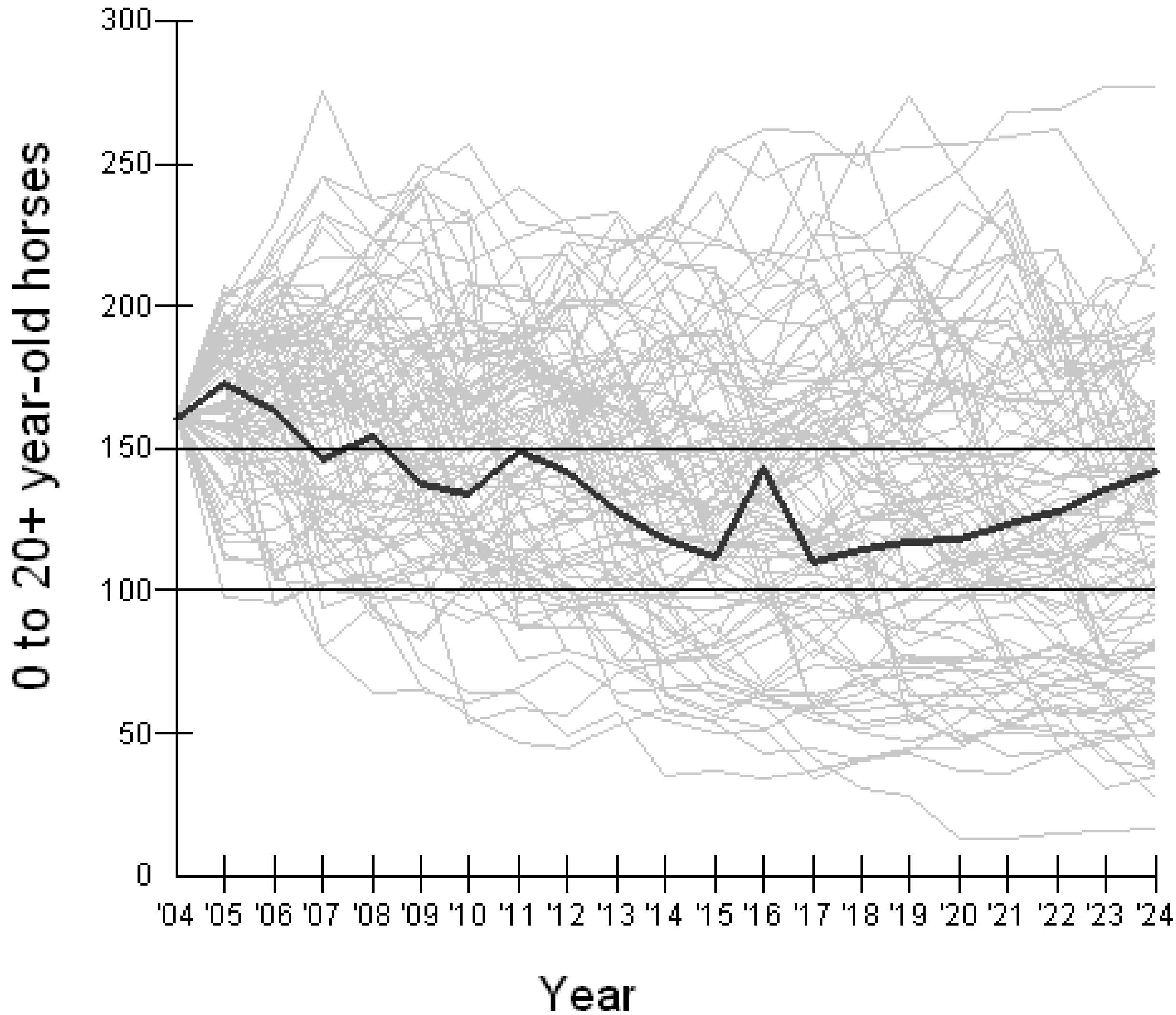

Figure 6. The "Most Typical Trial" simulated by the Jenkins model for the Pryor Mountain Baseline scenario.

Finally, as mentioned in the footnote added to Table 2, since running these simulations, newly collected data are available for the Clan Alpine herd (J.W. Turner, Jr., technical notes on Clan Alpine HMA Wild Horse Survey, June 2004, supplied by Linda Coates-Markle). These notes do not support 4th year effectiveness. Therefore, the cost estimates for scenarios involving the 3-year contraceptive will, of necessity, be too low.

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Appendix A. Listings of Jenkins Model Parameters for the Pryor Mountain HMA

The following table provides the basic parameters used in Jenkins' model simulations for the Pryor Mountain herd. Notes imbedded in the files used state that: (1) the initial age structure represented conditions in the fall of 2003 and was considered very accurate; (2) survival estimates represented 1996-2000 conditions, but assumed male survivals were about 97% that of females, as recorded for earlier (1976-1986) data; and (3) foaling rates represented 1996-2003 data, though no mares were ≥ 20 years old. In addition, Linda Coates-Markle confirmed that the initial population numbers by sex and age class should be considered exact counts and not a 90% value as was the case for previous simulations on other herds (Bartholow 2004).

Table A.1. Pryor Mountain Jenkins' model log file for Baseline Scenario. Foaling rates were entered with three digits of precision but only appear with two in this view. Also, log files incorrectly report that gathers do not continue after removals to treat additional females (Steve Jenkins, personal communication). This error has been corrected in this table.

Age Class	Initial Base Population		Survival Probabilities		Foaling Rates	Percentages for Removals		Percentages for Fertility Treatment
	Females	Males	Females	Males		Females	Males	
foal	10	12	0.700	0.700	0.00	0%	0%	0%
1	4	8	0.800	0.800	0.07	9%	9%	100%
2	8	8	0.931	0.902	0.48	9%	9%	100%
3	6	1	0.931	0.902	0.47	9%	9%	0%
4	4	7	0.930	0.901	0.64	4%	4%	0%
5	7	3	0.929	0.901	0.63	0%	0%	0%
6	6	6	0.929	0.900	0.64	0%	0%	0%
7	5	8	0.927	0.899	0.62	0%	0%	0%
8	4	3	0.925	0.897	0.71	0%	0%	0%
9	3	2	0.923	0.895	0.79	0%	0%	0%
10-14	16	17	0.907	0.879	0.58	0%	0%	50%
15-19	3	8	0.816	0.791	0.08	0%	0%	100%
20+	0	2	0.207	0.207	0.00	0%	0%	100%

```
Sex ratio at birth:  51% males
Scaling factors for annual variation:  survival probabilities = 1.00, foaling rates = 1.00
Correlation between annual variation in survival probabilities and foaling rates = 0.00

Management by removals and fertility control
Starting year is 2004
Gathering occurs at regular interval of 1 years
Initial gather year is 2004
Gathers for fertility treatment occur regardless of population size.
Gathers continue after removals to treat additional females.
Threshold population size for gathers is 150.
Target population size following removals is 100.
Foals are excluded from AML.
Percent of population that can be gathered = 70%.
Percent effectiveness of fertility control:  year 1 is  90%, year 2 is  0%, year 3 is  0%, year 4
is  0%, year 5 is  0%.
```

Table A.2. Pryor Mountain Jenkins' model log file for the more conventional 2-year contraceptive scenarios.

Age Class	Initial Base Population Females	Initial Base Population Males	Survival Probabilities Females	Survival Probabilities Males	Foaling Rates	Percentages for Removals Females	Percentages for Removals Males	Percentages for Fertility Treatment
foal	10	12	0.700	0.700	0.00	0%	0%	0%
1	4	8	0.800	0.800	0.07	50%	50%	100%
2	8	8	0.931	0.902	0.48	50%	50%	100%
3	6	1	0.931	0.902	0.47	50%	50%	0%
4	4	7	0.930	0.901	0.64	25%	25%	0%
5	7	3	0.929	0.901	0.63	0%	0%	0%
6	6	6	0.929	0.900	0.64	0%	0%	0%
7	5	8	0.927	0.899	0.62	0%	0%	0%
8	4	3	0.925	0.897	0.71	0%	0%	0%
9	3	2	0.923	0.895	0.79	0%	0%	0%
10-14	16	17	0.907	0.879	0.58	0%	0%	50%
15-19	3	8	0.816	0.791	0.08	0%	0%	100%
20+	0	2	0.207	0.207	0.00	0%	0%	100%

Sex ratio at birth: 51% males
Scaling factors for annual variation: survival probabilities = 1.00, foaling rates = 1.00
Correlation between annual variation in survival probabilities and foaling rates = 0.00

Management by removals and fertility control
Starting year is 2004
Gathering occurs at regular interval of 4 years
Initial gather year is 2004
Gathers for fertility treatment occur regardless of population size.
Gathers continue after removals to treat additional females.
Threshold population size for gathers is 150.
Target population size following removals is 100.
Foals are excluded from AML.
Percent of population that can be gathered = 70%.
Percent effectiveness of fertility control: year 1 is 94%, year 2 is 82%, year 3 is 68%, year 4 is 0%, year 5 is 0%.

Appendix B. Program to Estimate Economic Costs from WinEquus Simulation Results

As mentioned in Appendix A, the Jenkins model was used to simulate the population's alternative futures and the simulation results were written to a text file. A Microsoft VisualBasic program was constructed to read these results and calculate average yearly costs as well as overall average costs for a 20-year period. User-specified input to this program (Figure B.1) includes estimates for the individual components of the variable costs for each state.

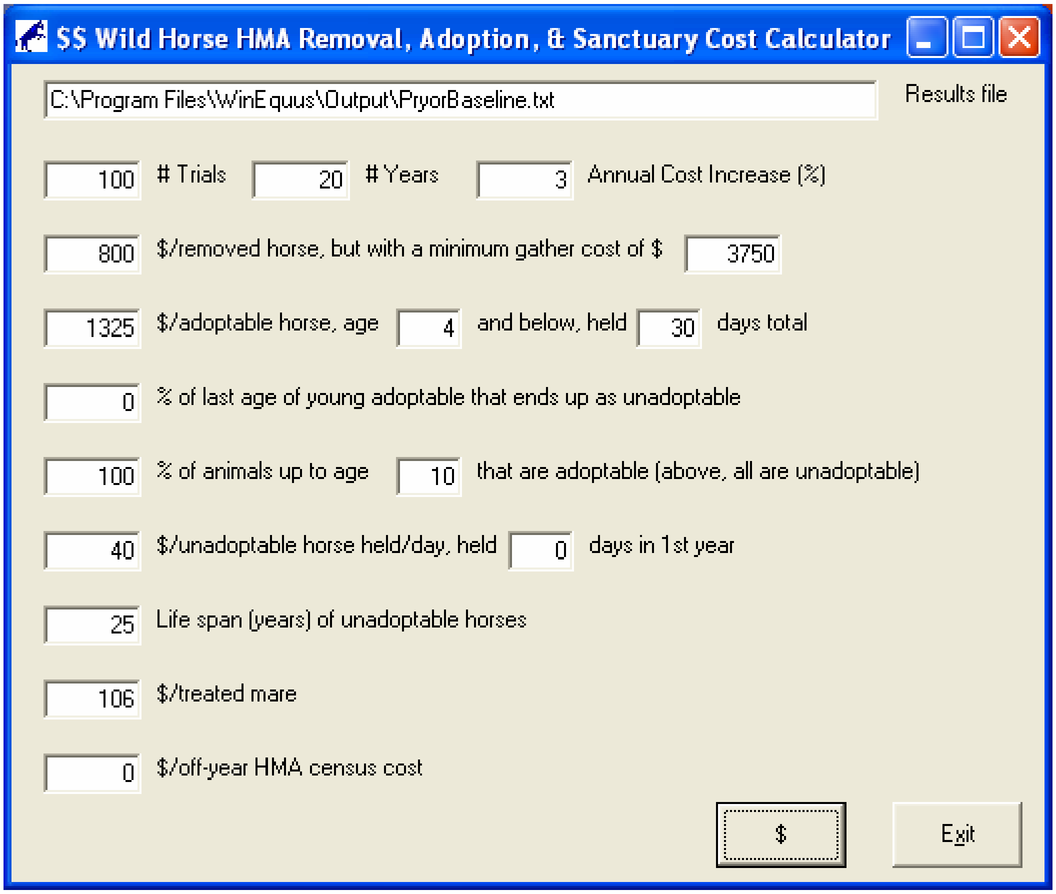

Figure B.1. Input parameters for companion program to estimate costs of each specific simulation run with the Jenkins modeling software. The image pictured is for the Baseline case and is considerably different from the more conventional scenarios. Note that since the Pryor Mountain herd produces only adoptable horses, cost values for that category will never apply. However, adoptable horses still accrue daily holding costs.

The number of *trials* and number of *years* are set to match parameters in the Jenkins model set-up. The number of trials and number of years capture both the variability inherent in the stochastic simulation model and any population adjustments in age and sex structure that occur over about one horse life span. The *annual cost increase* adjusts all future expenditures for the rate of inflation. The *$/removed horse* reflects the cost of gathering and removal averaged across all removed horses. *Minimum gather cost* is just what it says: i.e., even if the number of gathered horses is small, there would be a minimum cost just to have a gather. The *$/adoptable horse* reflects the combined cost of adoption and compliance checks (Table 3). All horses up to the first age listed are assumed to be adoptable, except for the *% of last age of young adoptable that ends up as unadoptable*. In other words, a certain percentage of the oldest age class of adoptable animals is considered unadoptable. [Note that since the Pryor Mountain herd does not produce unadoptable horses, this value is set to zero and therefore cost values for "unadoptable" horses will never apply.] Adoptable animals are held for the first number of *days* listed prior to adoption. A *% of animals up to age* xx are also considered adoptable. Unadoptable animals accrue a cost of *$/unadoptable horse held/day*, are held *days in 1st year*, and 365 days thereafter through their *life span*. Note that adoptable horses also accrue the same holding cost for the days they are held prior to adoption. Contraceptive application is reflected in the *$/treated mare* cost estimate. *$/off-year HMA census cost* reflects any additional costs involved with a contraceptive program in non-gather years (typically years 2 through 4), such as flight costs to assess treatment effectiveness and perform other routine monitoring (Hall 2003). This last item would be zero except for scenarios involving contraceptive treatment.

The program reads the simulation results, averaging the costs for each year over the number of trials for which the software was run, and then summarizes the results across all simulation years. The output from this program looks like that shown in Table B.1.

The economic model output contains the name of the Jenkins model simulation results file and echoes the input values used. *Expenses* are inflation-adjusted values and *CV* is the coefficient of variation: i.e., the percent that expenses might be expected to vary annually given the variability reflected in the stochastic population model. The CV value is calculated as one standard deviation from the mean value for the year divided by that mean value. The remaining values listed (population size, sex ratio, number gathered, number treated, number removed, number adopted, number unadoptable, number held, and number dying) also represent annual averages, rounded to the nearest animal. The *mean* values listed near the bottom are averages across the number of years, except for those associated solely with gathering (population size, sex ratio, number gathered, number treated, number removed, number adopted, number unadoptable), which are averaged across the number of gathers. Finally, the program provides the percentage of the mean annual expense attributable to the total cost of adoptions, long-term holding, and contraceptive treatment.

Scanning the values listed in Table B.1, one can usually see how the population is adjusting through time to the management strategy implemented in the population modeling software. It is also a useful way to assess whether the selective removal rates specified in the Jenkins model have been effective in reaching the specified herd-specific AML – if foals are included in the AML.

Table B.1. Example output from cost estimator program for Pryor Mountain Baseline Scenario.

```
C:\Program Files\WinEquus\Output\PryorBaseline.prn  6/17/2004  9:01:26 AM
Trials = 100   Years = 20   Inflation % = 3
$/Removed horse = 800 , with minimum gather cost = 3750
$/Adoption = 1325 up to age 4 and held 30 days
0 % of last 'fully' adoptable age diverted to unadoptable
100 % of ages up to 10 that are adoptable
$/Unadoptable/Day = 40 held 0 days the 1st year
Life span (yrs) = 25       $/Treated mare = 106
$/Off-year census = 0 (Include for treatment scenarios only!)
```

Year	Expense	±_CV	PopSize	SexRat	Gather	Treat	Remove	Adopt	UnAdopt	Held	Die
1	$939	19.2%	161	0.528	97	9	0	0	0	0	0
2	$2,982	180.5%	168	0.513	105	8	1	1	0	0	0
3	$9,403	108.6%	168	0.507	106	13	2	2	0	0	0
4	$8,592	119.5%	163	0.505	102	14	2	2	0	0	0
5	$9,583	124.5%	160	0.502	100	12	2	2	0	0	0
6	$8,479	138.5%	158	0.504	99	12	2	2	0	0	0
7	$7,825	143.9%	152	0.502	96	12	2	2	0	0	0
8	$7,216	152.2%	151	0.504	98	11	1	1	0	0	0
9	$7,797	145.8%	148	0.506	96	11	1	1	0	0	0
10	$7,192	156.5%	143	0.503	93	11	1	1	0	0	0
11	$6,885	162.4%	139	0.502	90	11	1	1	0	0	0
12	$6,652	174.6%	136	0.501	89	10	1	1	0	0	0
13	$5,741	193.6%	134	0.502	87	10	1	1	0	0	0
14	$6,984	176.3%	136	0.502	89	10	1	1	0	0	0
15	$7,345	180.0%	134	0.507	88	11	1	1	0	0	0
16	$7,312	162.4%	133	0.509	86	10	1	1	0	0	0
17	$8,924	156.4%	132	0.509	86	10	1	1	0	0	0
18	$9,180	164.7%	131	0.510	85	10	1	1	0	0	0
19	$8,603	180.6%	127	0.506	83	10	1	1	0	0	0
20	$7,752	178.1%	123	0.505	80	9	1	1	0	0	0
Mean	$7,269	154.3%	145	0.506	98	11	1	1	0	0	0

```
79.1% for Adoptions
 0.0% for Holdings
20.9% for Treatment
```